Preparation of Thallium target for fusion-fission studies

Golda K.S.[1,2],* Abhilash S.R.[1], A. Saxena[3], V.K. Mittal[2], D. Kabiraj[1], and S. Kailas[3]
[1]Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India
[2]Physics Department, Punjabi University, Patiala, Punjab 147002, India and
[3]Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, India

Introduction

Study of fusion-fission dynamics throws light into the mechanisms involved in nucleus-nucleus collision, particularly in view of the production of super heavy elements, one of the major motivation of present day nuclear physics research. Self supporting targets of heavy elements are highly required for such studies. Presently we are interested in studying the effects of neutron shell closure in nuclear reaction dynamics around mass 200 region through neutron multiplicity measurements. In order to produce the compound nuclei of our interest (^{220,212}Po), we proposed to carry out fusion reaction of ^{7}Li beam on ^{203,205}Tl targets.

Various methodologies are adapted in preparing isotopic targets for Nuclear Physics experiments based on the experimental requirements and physical and chemical properties of the material. We require targets of $\sim$2mg/cm^2 for the present study in which we are interested to measure the neutrons in coincidence with fission fragments. As the fission cross section in the proposed reactions are estimated to be low, we prefer to have a thick enough target to enhance the fission-neutron coincident yield. Nevertheless, the target thickness should be such that the fission fragments produced in the reactions should be able to come out of the target with sufficient energy to get registered in the gas detectors used for fission fragment detection. The details of the experimental set up is described elsewhere [1]. Based on the demands of the present experimental conditions we have opted mechanical rolling of the material to prepare the target.

*Electronic address: goldaks@gmail.com

Properties of Thallium

Thallium is extremely soft, malleable, sectile, low-melting, silvery metal. It has a metallic luster that, when exposed to air, quickly tarnishes to a bluish-gray tinge, resembling lead. This group IIIA element is highly chemically reactive. ^{203}Tl and ^{205}Tl are the only stable isotopes of Tl with an abundance of 70.5% and 29.5% respectively. As the preparation of Tl targets has not yet been reported in the literature, optimization of the rolling procedures needs special attention considering its physical and chemical properties.

Principles of Mechanical Rolling

Cold pack rolling is one of the efficient method for the preparation of self supporting targets of 1-10mg/cm^2 thickness of high purity material. The minimal material lost involved in the procedure makes it attractive for the preparation of foils of expensive isotopically enriched materials of rare stable isotopes. Metal rolling has been defined basically as the deformation of a metal shape by means of a set of shaped rollers in a conventional mill (Fig. 1). In this method the metal to be rolled is placed between stainless steel packs. The procedure will vary for different metals according to its mechanical properties, purity, and initial shape. The minimum rolled thickness for various metals will also differ with their mechanical properties, density, and chemical reactivity. The mechanical property of the material is a major determining factor in rolling. The material undergoes plastic (irreversible)deformation during the process of rolling. Ductile metals, which are normally considered for rolling, do have a large range of plastic deformation in the stress-strain dia-

FIG. 1: Picture of rolling machine used

gram, however the critical shear stress drastically changes with the elemental and chemical purity of the material [2].

Cold Rolling of Thallium

A small piece of Thallium cut out of 12.5mm diameter 75mm long rod was used for preparing the target. The metal rod of 99.9% purity was supplied by Alfa Aesar. The areal density of the Thallium piece used was of about 850mg/cm^2. The initial rolling was done using mirror polished folded stainless steel pack of 6 cm wide and 7.5 cm long. As the material is very soft, within few turns of roll pass the thickness was reduced to 150mg/cm^2. A small square shaped piece of the rolled metal was used for further rolling. Even though everything (stainless steel rolling pack, tweezers, etc.) was kept very clean, when a thickness of about 6mg/cm^2 the foils started to stick to the stainless steel pack. Opening the pack to check the thickness caused the formation of bubbles and blisters which made the foil to rupture even after the application of silicon oil on the foil during rolling process. It is to be noted that Tl is highly oxidizing in nature and few hours of exposure to air during the process of rolling made the foil to form metal oxides on its surfaces which considerably reduces the ductility. It has been reported earlier [2] that the oxide dispersoids affects the shear strength of the material and there by the material deformation during foil processing.

As the above mentioned approach was inadequate to produce target of required thickness, the following method was adapted. A 7.5cm wide and 7.5cm long folded pack of Teflon (Polytetrafluroethelene) was used for rolling the foil below 100mg/cm^2 thickness. It was important to have scratch free Teflon sheet for this purpose. After every 20-25% reduction in thickness, section of foil having a known area is cut from the foil and weighed to estimate the thickness. This section was further rolled down till the thickness had reduced to 10mg/cm^2. The foil was dipped in acetone to remove dust and other impurities. From this stage onwards the sides of the foils were trimmed by removing the distorted edges to get foils of smaller area for further rolling. After reaching a thickness of 6mg/cm^2 the removal of the foil by use of a paper piece for reversing the direction became extremely difficult. At this stage removal of the foil was made easy by soaking the entire Teflon piece with the foil in acetone. Final thickness achieved by using this procedure was 2.5mg/cm^2. Many unsuccessful trials were made to reduce the thickness further down by the usage of Silicon oil. The prepared targets of required thickness was kept in Argon environment to avoid oxidation of the material.

The error in target thickness estimation using the mentioned method is limited by the instrument uncertainty. The area of the foil is measured by graph paper with a precision of 1mm^2 and the weight is measured using microbalance with a precision of 0.01mg.

Conclusion

We have prepared self supporting targets of ^{nat}Tl of 2.5mg/cm^2 by using cold rolling technique. Use of Teflon sheet as rolling pack was extremely helpful in achieving the required thickness. The same method will be adapted for preparing enriched targets of Tl.

References

[1] Golda K. S., et al., DAE Symp. on Nucl. Phys. ,Vol.55, (2010) 262.

[2] S. Clifford et al., Nucl. Instr. and Meth. A 480 (2002) 29